The SN 1987A Beam/Jet and Its Associated Mystery Spot

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Very early measurements of SN 1987A (87A) can be interpreted in terms of an intense beam of light and jet of particles (BJ), which still ran ahead of a slower, cooler, shrouding flow, cooled itself, or lost the ability to do so, before impacting polar ejecta (PE) remaining from the previous binary merger which formed Sk -69^{o} 202. The photon beam scattered off/reprocessed in, without significantly penetrating, the PE, producing 2×10^{39} ergs/s for about a day at day 8.0, the *same* delay *predicted* from the 0.059″ offset (17 light-days in projection) of the "Mystery Spot" (MS), and the ring/bipolar geometry (the many other details of 87A also strongly suggest that it resulted from a merger of 2 stellar cores of a common envelope [CE] binary, i.e., a "double-degenerate" [DD] event). This scattered flux then decayed for a day with a timescale *consistent* with the UV flash, after which the luminosity rebounded to the day 8.0 value by day 10.0, and continued rising linearly with time, indicating: (1) particles from the jet penetrating into the PE, with (2) the fastest traveling >0.9 c, and (3) that both the beam and jet had collimation factors $>10^{4}$. Without having to penetrate the entire CE of Sk -69 202, it is likely that the BJ would have produced a full, long/soft, "ℓGRB" upon impacting the PE. Because DD can produce ℓGRBs, and dominates in elliptical galaxies, where *only* sGRBs have been observed, DD without CE and PE *also* produces sGRBs, and thus the pre/non-CE/PE photon spectrum of 99% of GRBs is known, and NS-NS mergers may not make GRBs as we know them, and/or be as common as previously thought. MSPs in the non-core-collapsed globular clusters are also 99% WD-WD DD merger, consistent with their 2.1 ms minimum spin period, the 2.14 ms signal seen from SN 1987A, and sGRBs offset from the centers of elliptical galaxies. There is *no need* to invent exotica, such as "collapsars," to account for ℓGRBs.

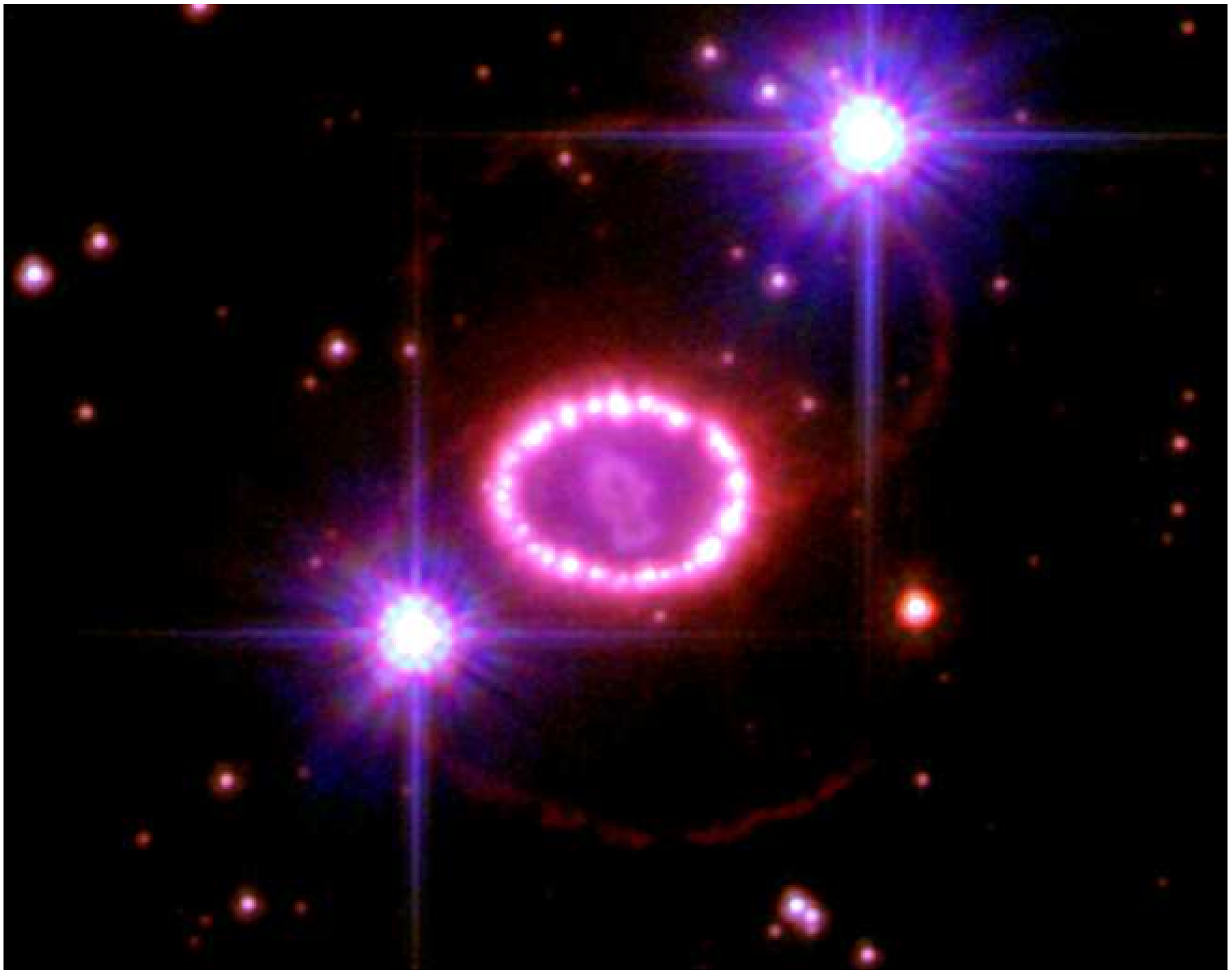

Fig. 1. SN 1987A as of December 2006, as viewed with the HST (NASA, P. Challis, & R. Kirshner, Harvard-Smithsonian Center for Astrophysics). North is up, east is to the left. The bipolarity of the explosion is suggestive of (electron) degenerate core-core merger-induced collapse ("Double Degenerate" – DD). The axis of the bipolarity corresponds to the "Mystery Spot" bearing of 194° (the far-side [southern] minor axis of the equatorial ring has a bearing of 179°).

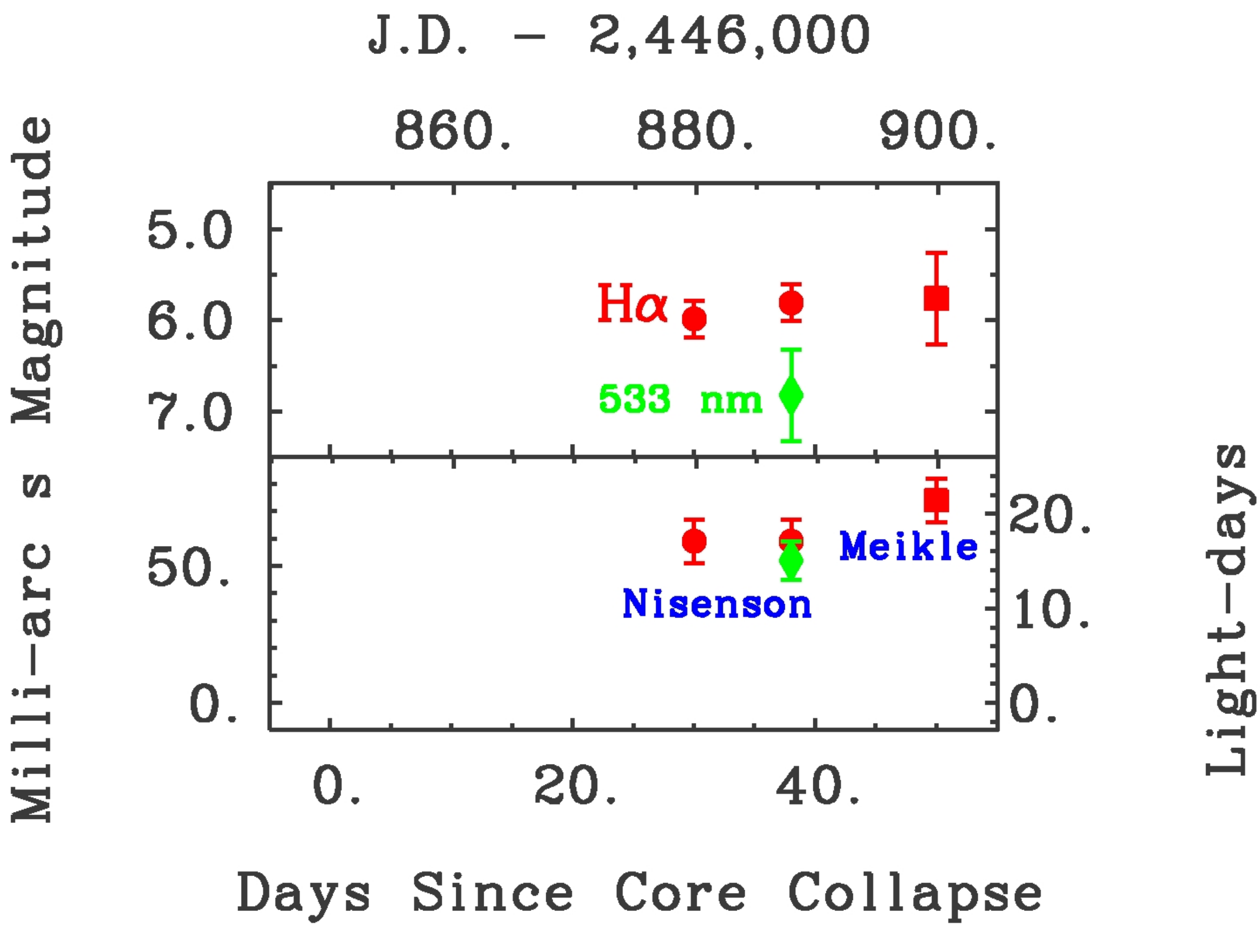

Fig. 2. Measurements of displacement (lower) and observed magnitude (upper) of the "Mystery Spot" (MS) from SN 1987A, at Hα and 533 nm, vs time, from Nisenson et al. 1987, ApJ, 320, L15, and Meikle et al. 1987, Nature, 329, 608.

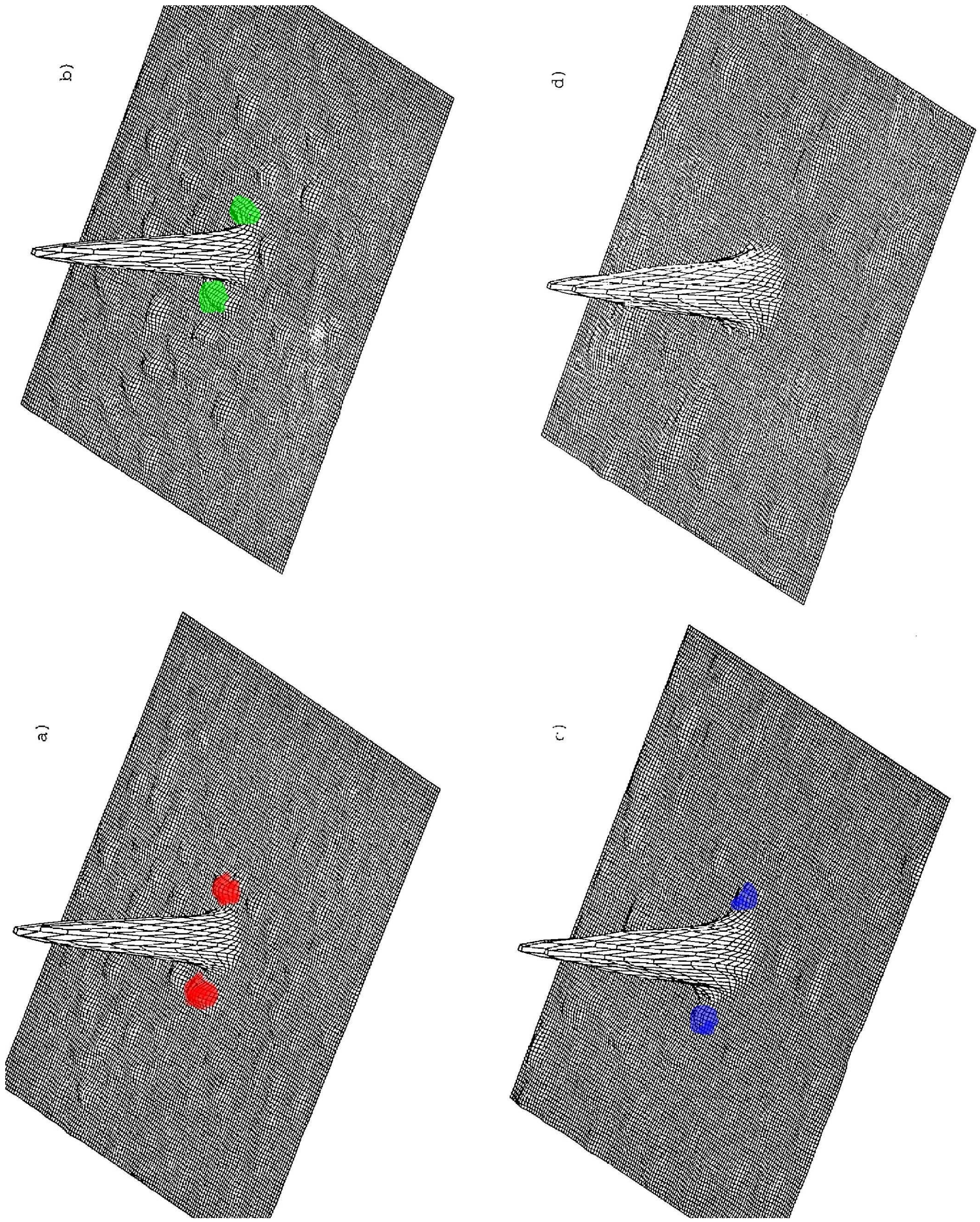

Fig. 3. From Nisenson et al. 1987, ApJ, 320, L15, SN 1987A and the "Mystery Spot" (a – lower left) in Hα (the 180^o ambiguity is an artifact of the reconstruction technique), (b – upper left) 533 nm, (c – lower right) 450 nm, and (d – upper right) comparison star, ν Doradus. This feature was seen 30, 38, and 50 days *after* core-collapse, with an associated total energy of 10^{49} ergs, of which some 3% was eventually radiated into the optical.

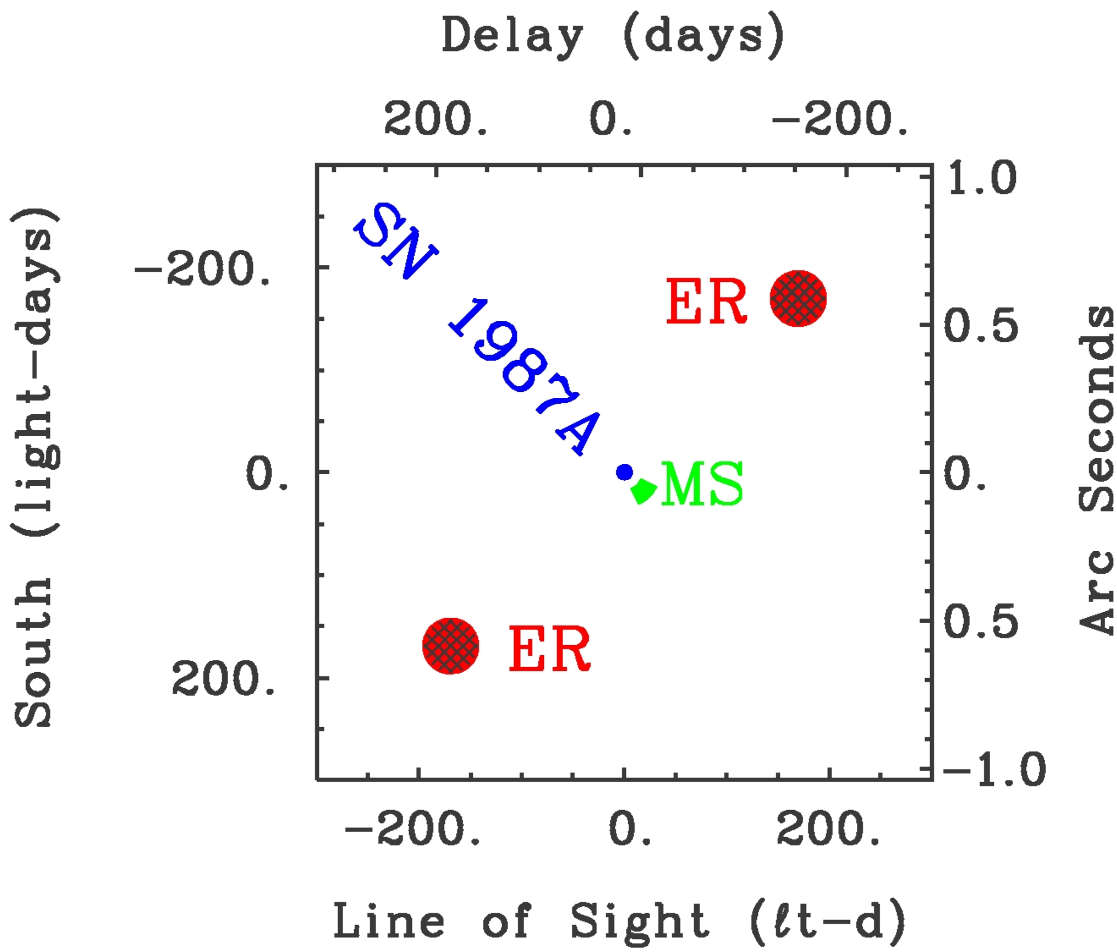

Fig. 4. The geometry of the "Mystery Spot" (MS) relative to SN 1987A and the equatorial ring (ER -- shown in cross-section).

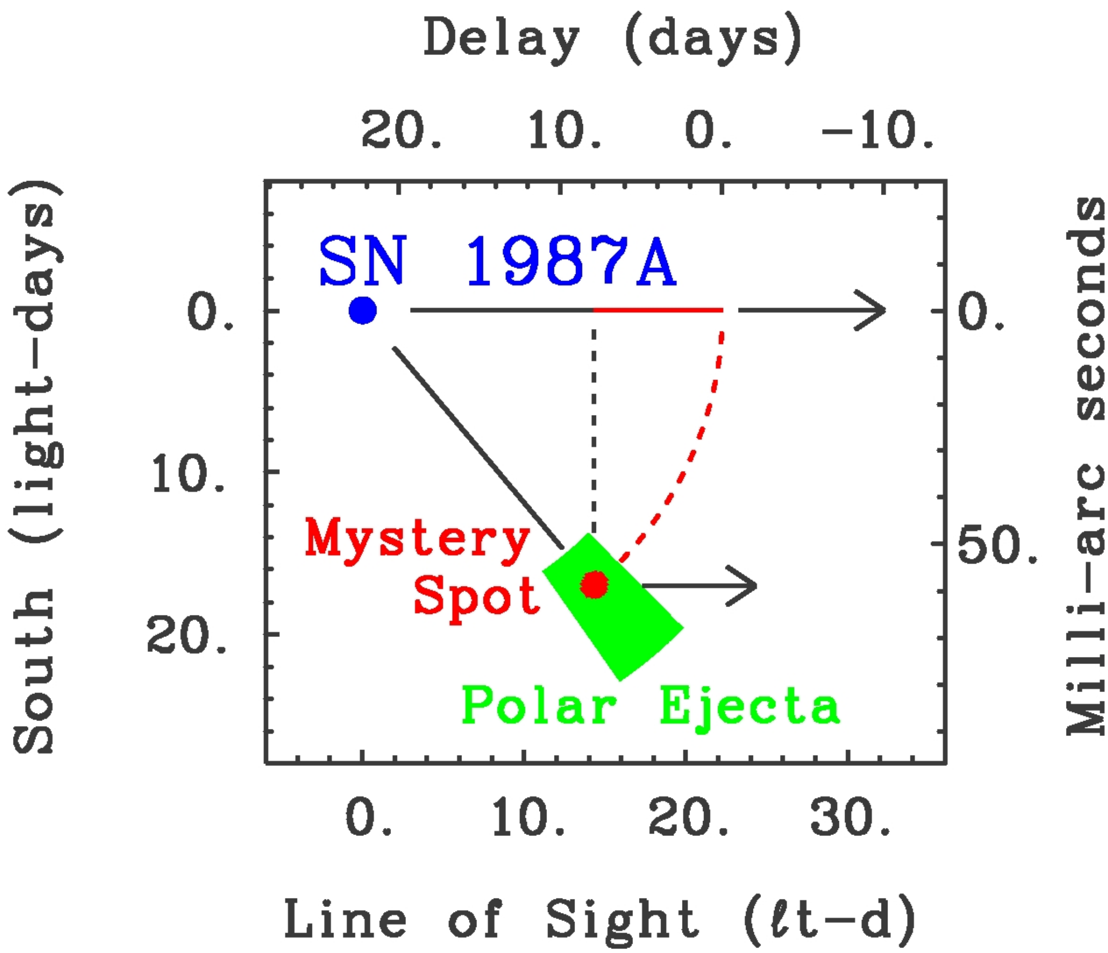

Fig. 5. The geometry of the "Mystery Spot," (MS) associated beam/jet, and direct line of sight from SN 1987A. It takes an extra *eight* days for light from 87A to hit the Polar Ejecta (PE), making the MS in the process, and proceed on to the Earth. The distance from 87A to the MS is some 22 light-days. An offset by the 0.5^{o} collimation angle of a GRB over this distance would delay the flux by about 100 s, the characteristic delay for long duration, soft spectrum GRBs (ℓGRBs).

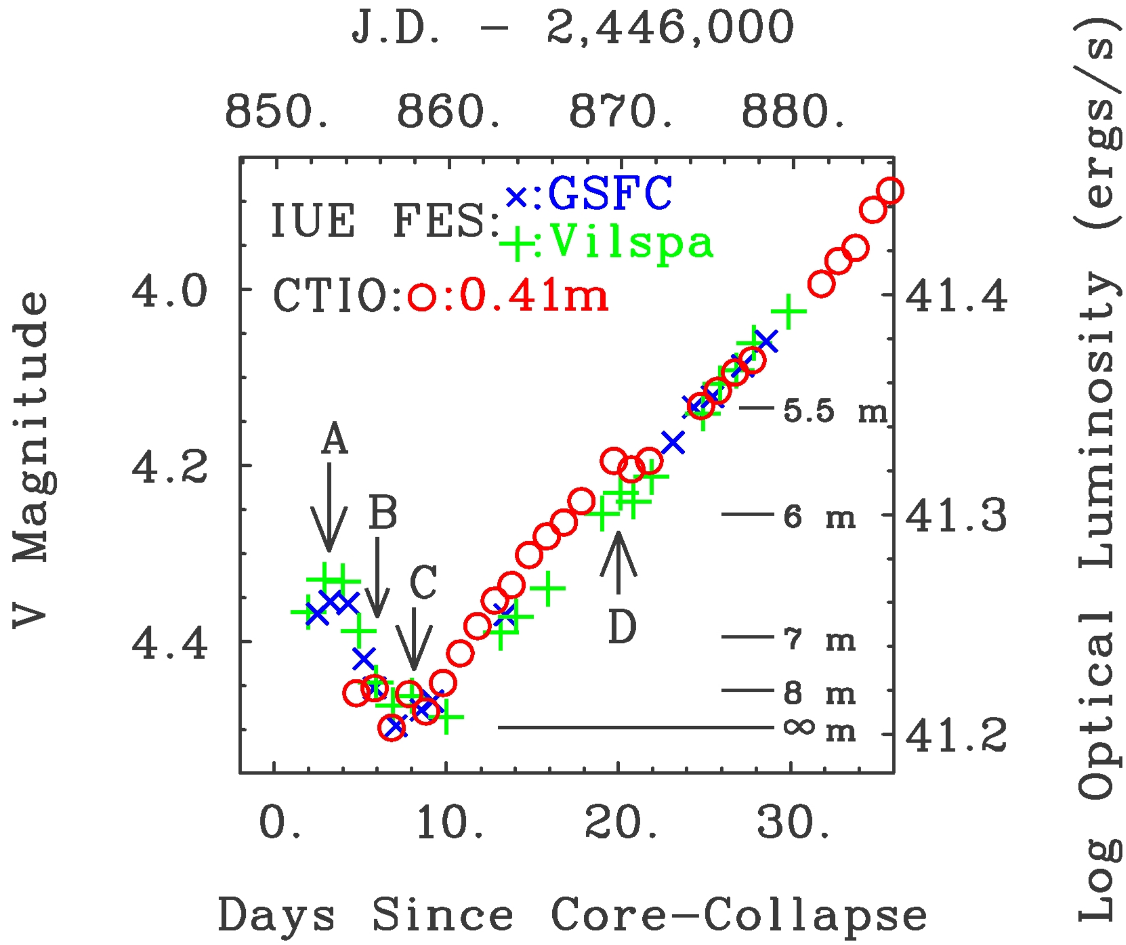

Fig. 6. After Hamuy & Suntzeff 1990, AJ, 99, 1146, and Wamsteker et al.1987, A&A, 177 L21, the very early luminosity history of SN 1987A as observed with the CTIO 0.41-m and the Fine Error Sensor of IUE. Data taken at Goddard Space Flight Center by Sonneborn & Kirshner, and the Villafranca Station in Madrid, Spain, are marked as blue X's, and green +'s, respectively. Various stages of beam/jet breakout and interaction with polar ejecta are labeled. The flux level near day 20 corresponds to 5.8 magnitudes above the day 7 minimum, the *same* as that of the MS in Hα measured nears days 30, 38, and 50. The decrement here is actually preceded by a *spike* with strange colors (B, R, & I, but little U or V -- see Fig. 17).

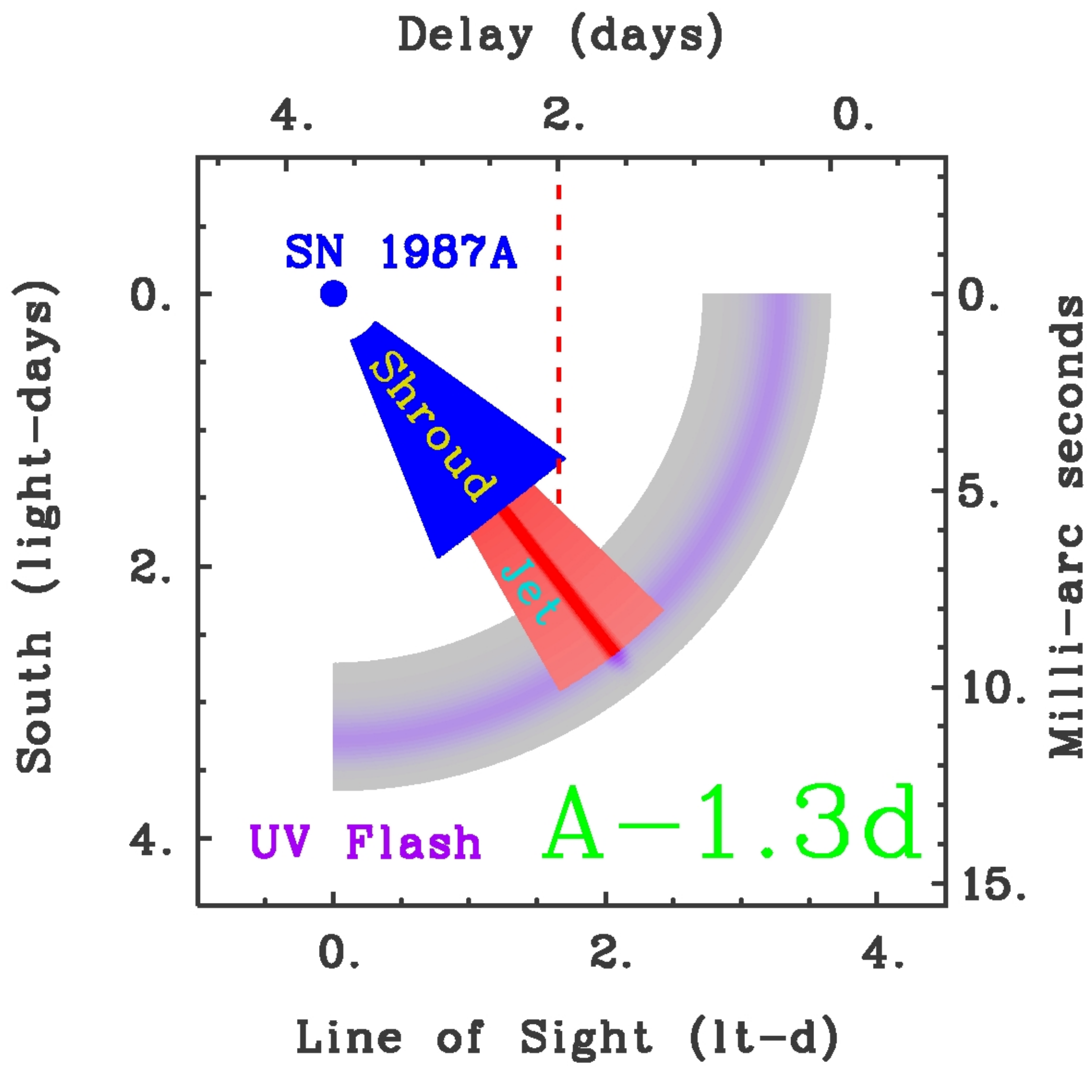

Fig. 7. The geometry of the 87A glowing beam/jet (BJ), initially opaque shroud, and UV Flash (which may have an enhanced beam of its own in the jet direction (here 52^o, down and to the right). The center of the emerging jet produces the rising luminosity shown in Fig. 6 at day 2 (read on the upper, delay scale). The maximum velocity of the jet is 0.92 c, that of the shroud, 0.55 c. Because of the short time response of the luminosity shown in Fig. 6 full angular width of the jet has been set to 1.04^o.

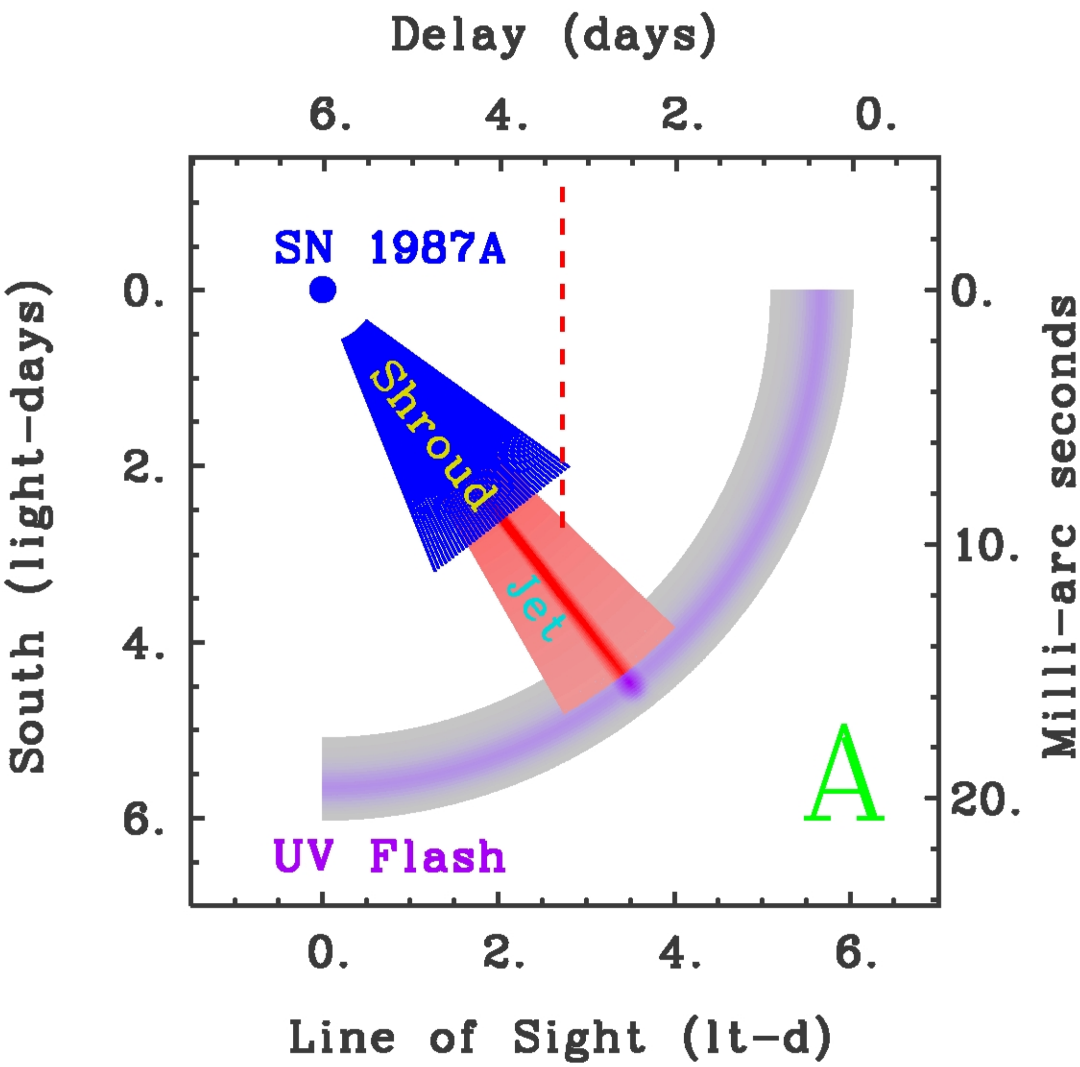

Fig. 8. The geometry of the 87A glowing beam/jet (BJ), initially opaque shroud, and UV Flash. The center of the emerging jet produces the rising luminosity shown at point 'A' in Fig. 6 at day 3.3 (read on the upper, delay scale).

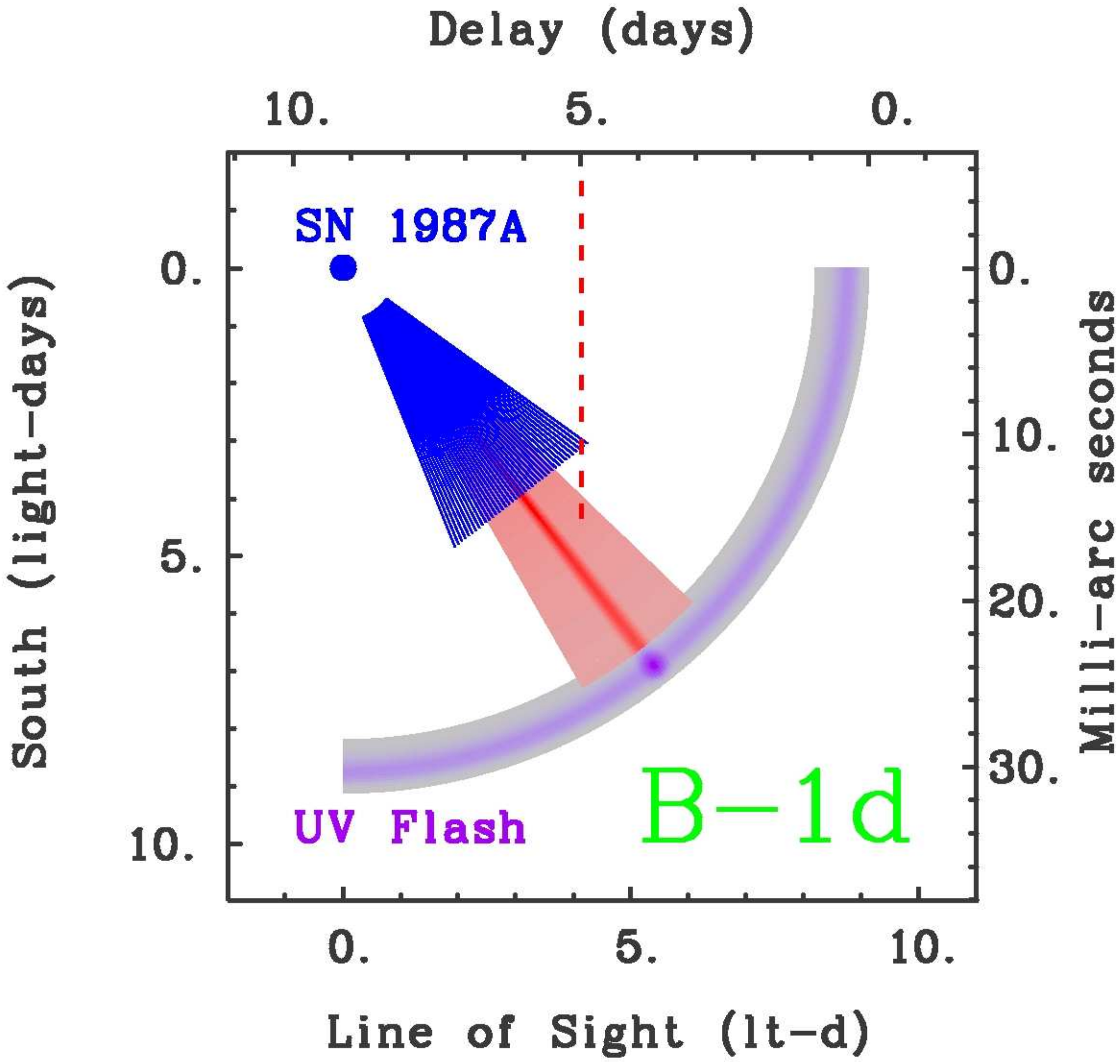

Fig. 9. The configuration in which the light from the center of the exposed part of the now fading jet lies on the dropping luminosity curve at day 5 (one day prior to point ‘B’ in Fig. 6).

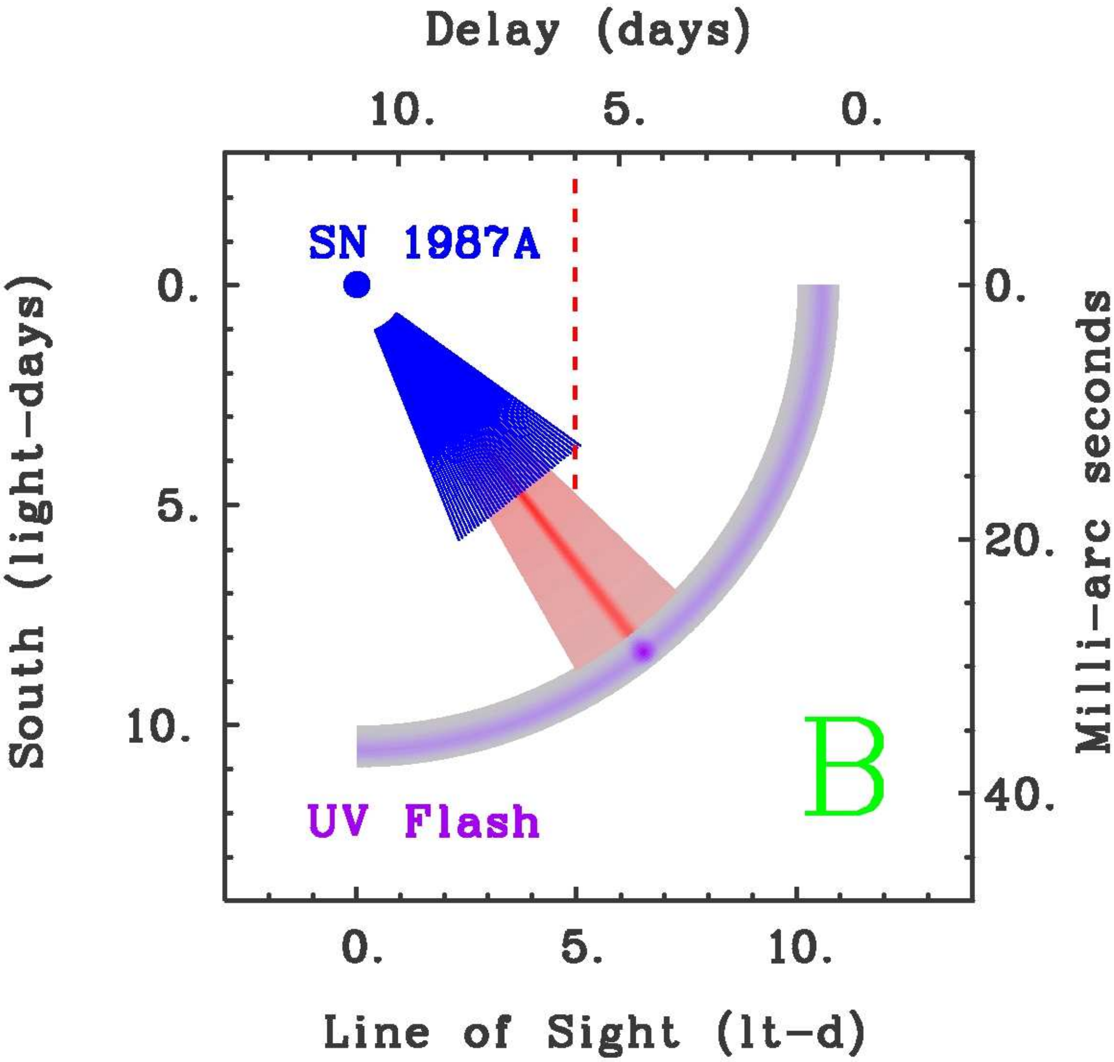

Fig. 10. The configuration in which the light from the center of the exposed part of the now fading jet lies on the dropping luminosity curve at day 6 (point ‘B’ in Fig. 6).

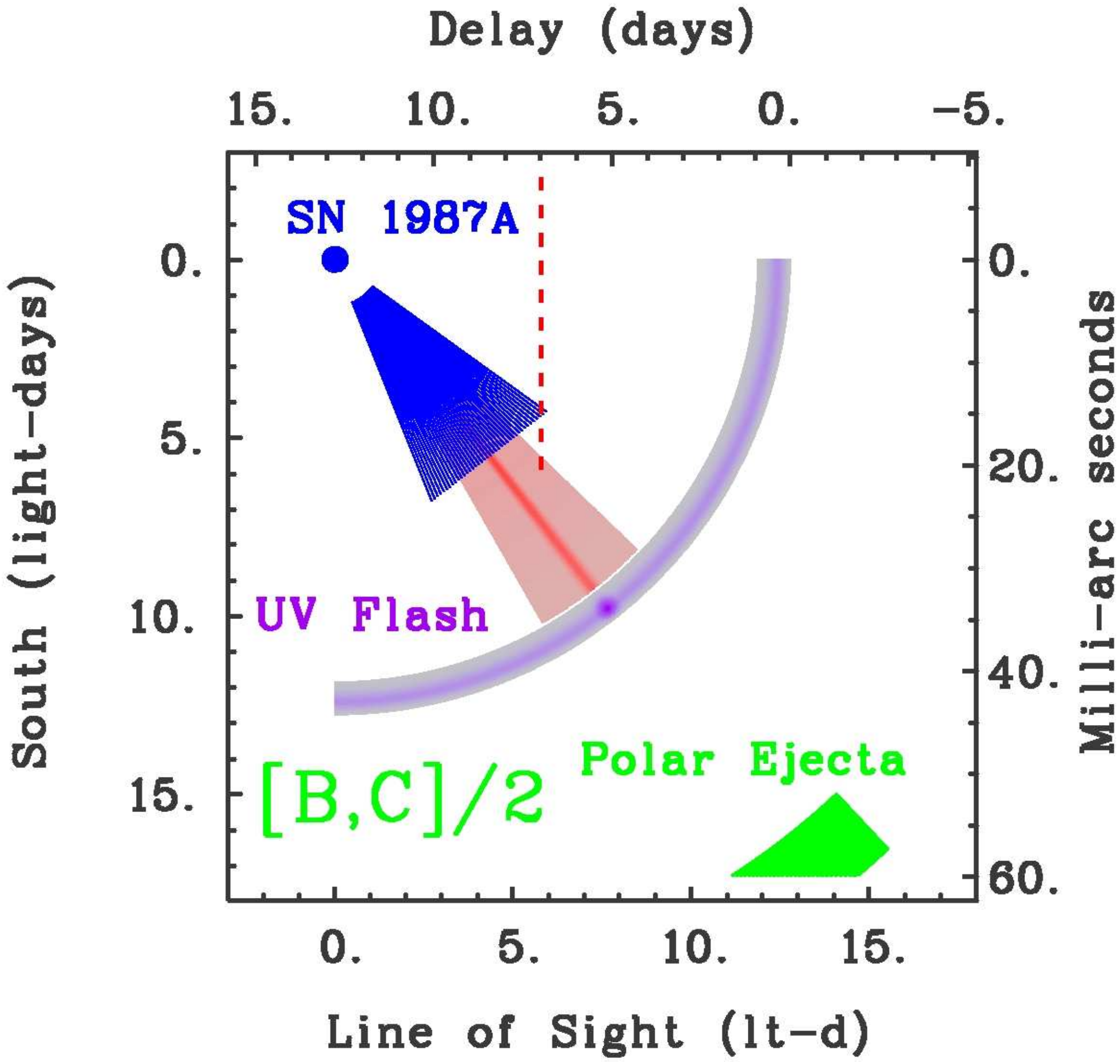

Fig.11. The configuration in which the light from the center of the exposed part of the still fading jet lies near the minimum of luminosity curve near day 7 (between 'B' and 'C' in Fig. 6). Polar Ejecta some 20.54 light-days distant and 2.16 light-days thick appears in green at the lower right.

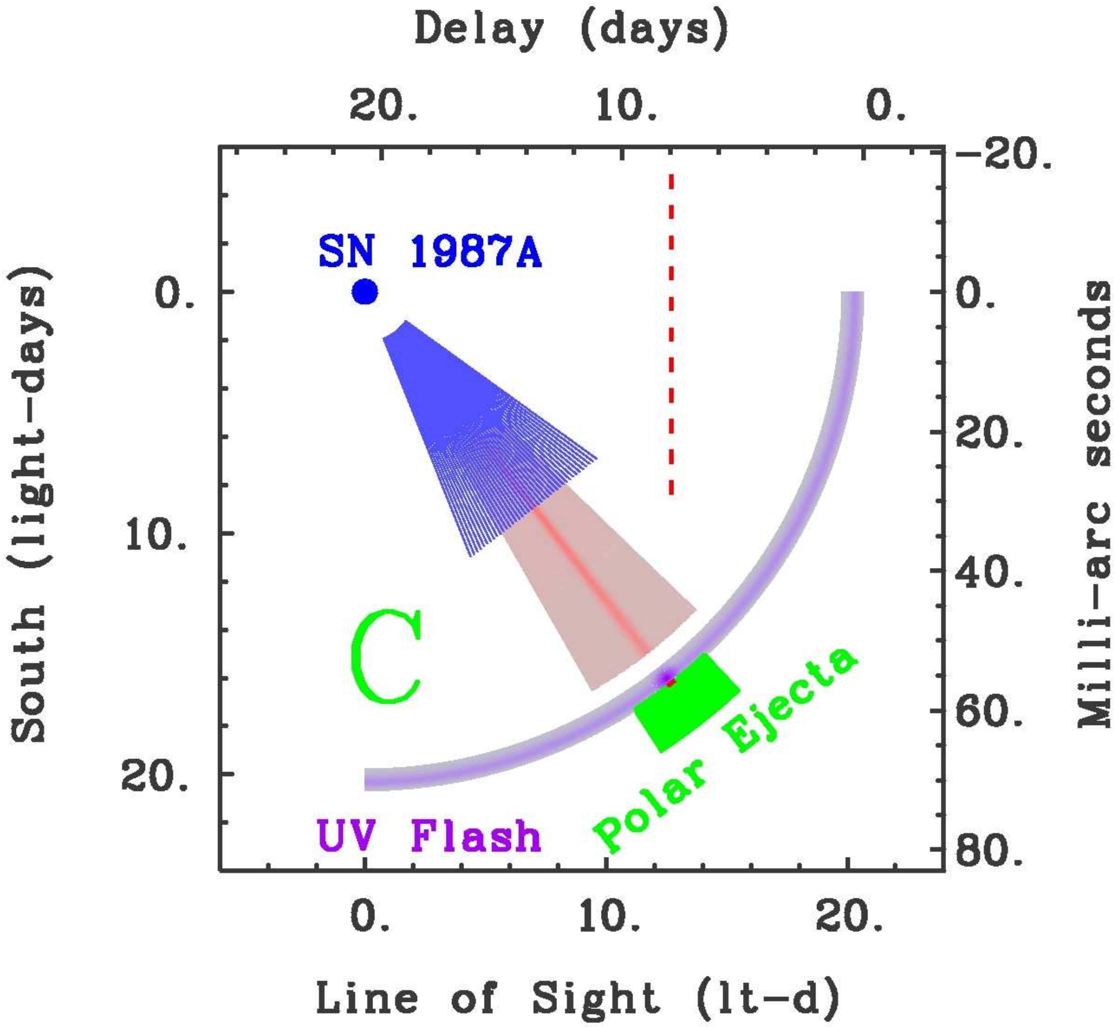

Fig. 12. The intense beam of the UV Flash scatters and reprocesses off the polar ejecta, producing the jump in luminosity at day 8 (top scale for the tiny red disk in the PE and 'C' in Fig. 6 – some 2x10^{39} ergs/s for a day). A polar ejecta density of 10^7 cm^{-3} would predict that the UV Flash does not penetrate it deeply, and this is confirmed by the dropoff of luminosity near day 9 in Fig. 6. The tiny red disk corresponds to the highly collimated (~1^o) intense beam of the UV Flash, and can not be much larger all because of the fast rise/drop in luminosity before/after day 8 in Fig. 6, and thus its collimation factor is >10^4.

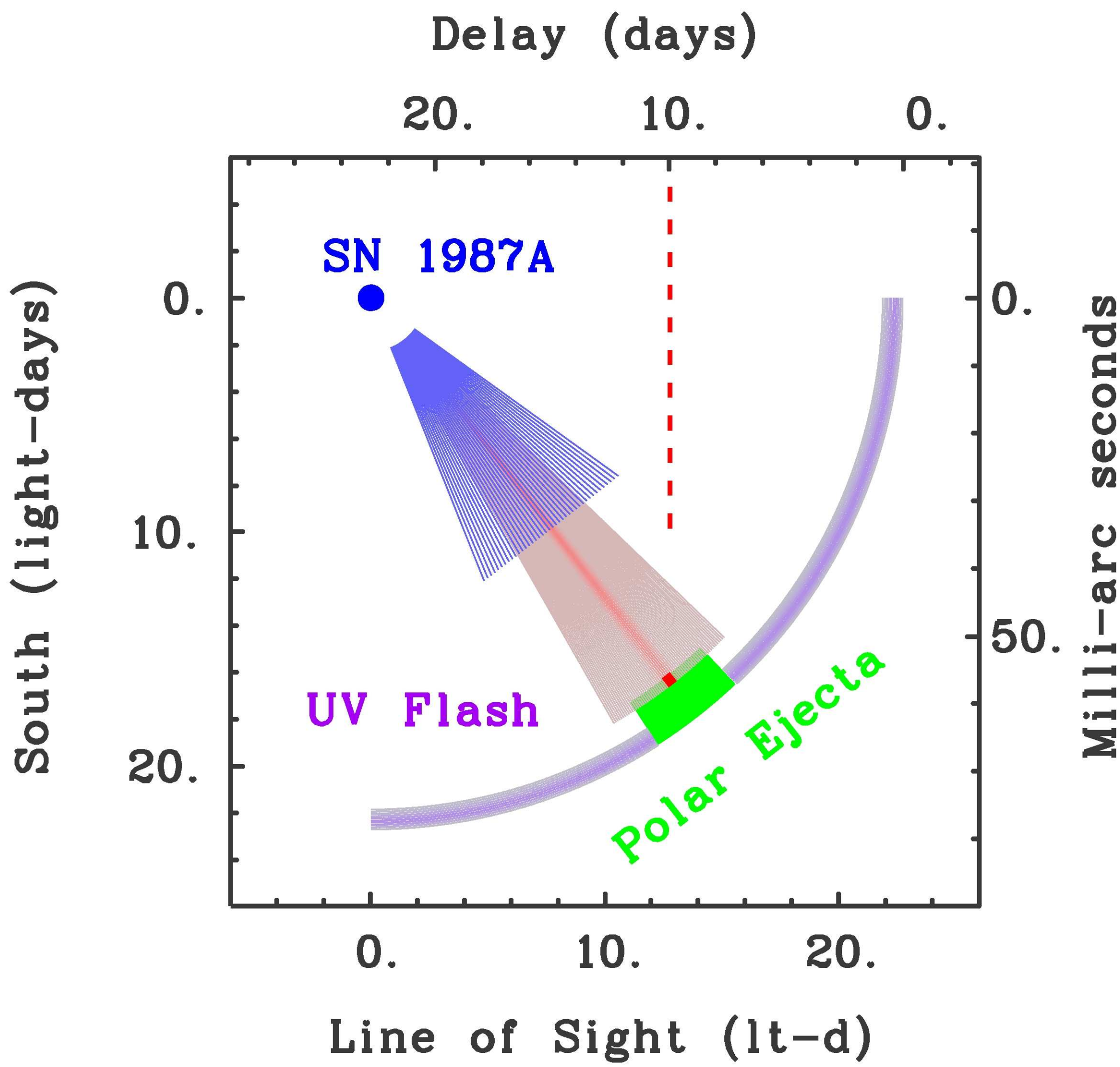

Fig. 13. The intense center (~1°) of the jet begins to produce light (red) as it penetrates into the polar ejecta (green), producing the jump in luminosity at day 10 (again, top scale for the red spot in this figure [11]), visible in Fig. 6 for the same time. The penetration may continue because the cross sections for this process are orders of magnitude smaller than for the UV Flash. The 0.059″ offset of the spot corresponds (loosely) to measurement of the "Mystery Spot" shown in Figs. 2, 3, 4, and 5. The collimation factor for the jet is also $>10^4$.

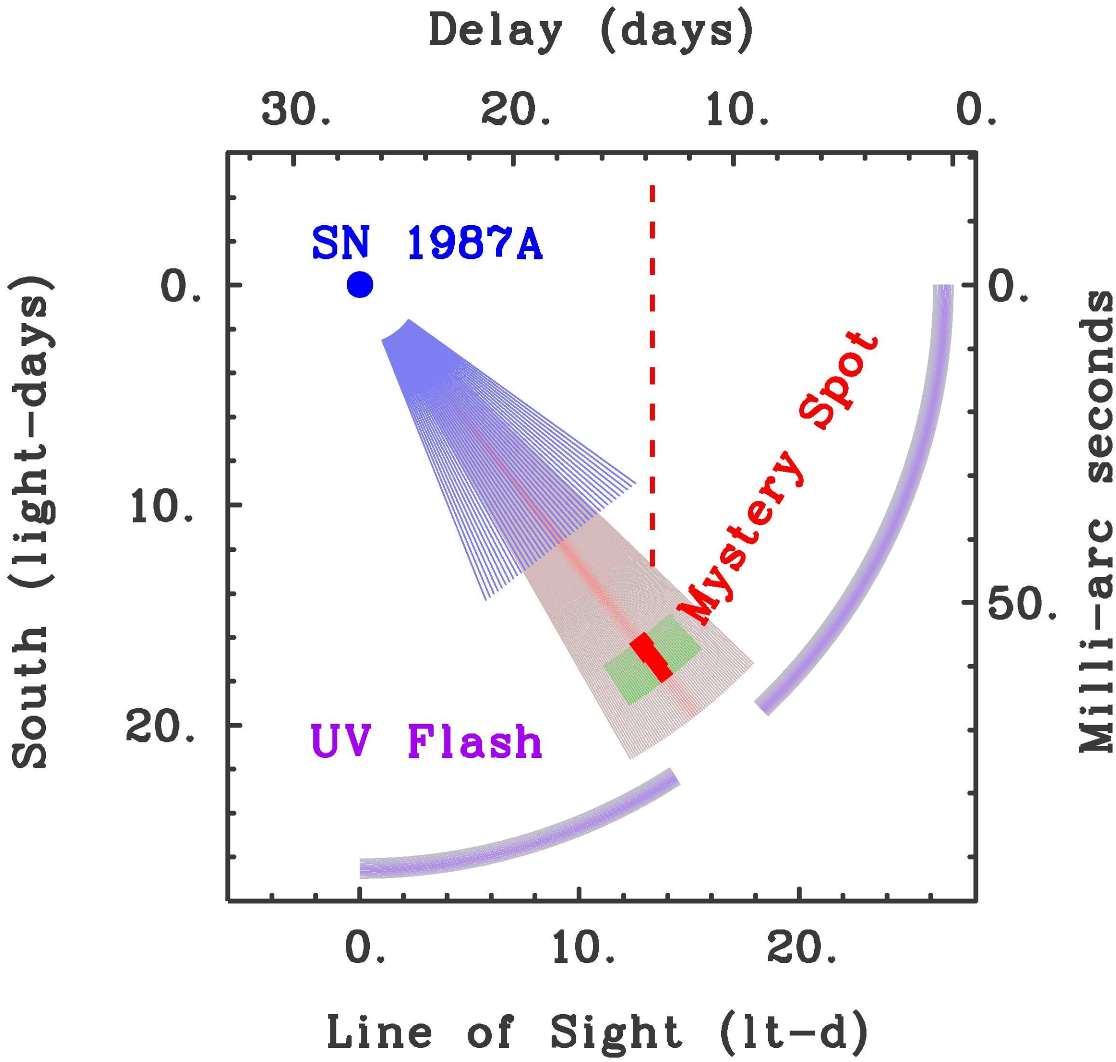

Fig. 14. The jet continues to impact the polar ejecta (green), to produce the ramp in luminosity visible in Fig. 6 near day 13.5 (top scale for the red strip in *this* figure [14]), and the Mystery Spot observed later at days 30, 38, and 50. The CTIO and FES V bands have peaks near 550 and 510 nm respectively, accounting for the small difference between the two curves in Fig. 6. The CTIO and FES V bands have peaks near 550 and 510 nm respectively, accounting for the small difference between the two curves in Fig. 6.

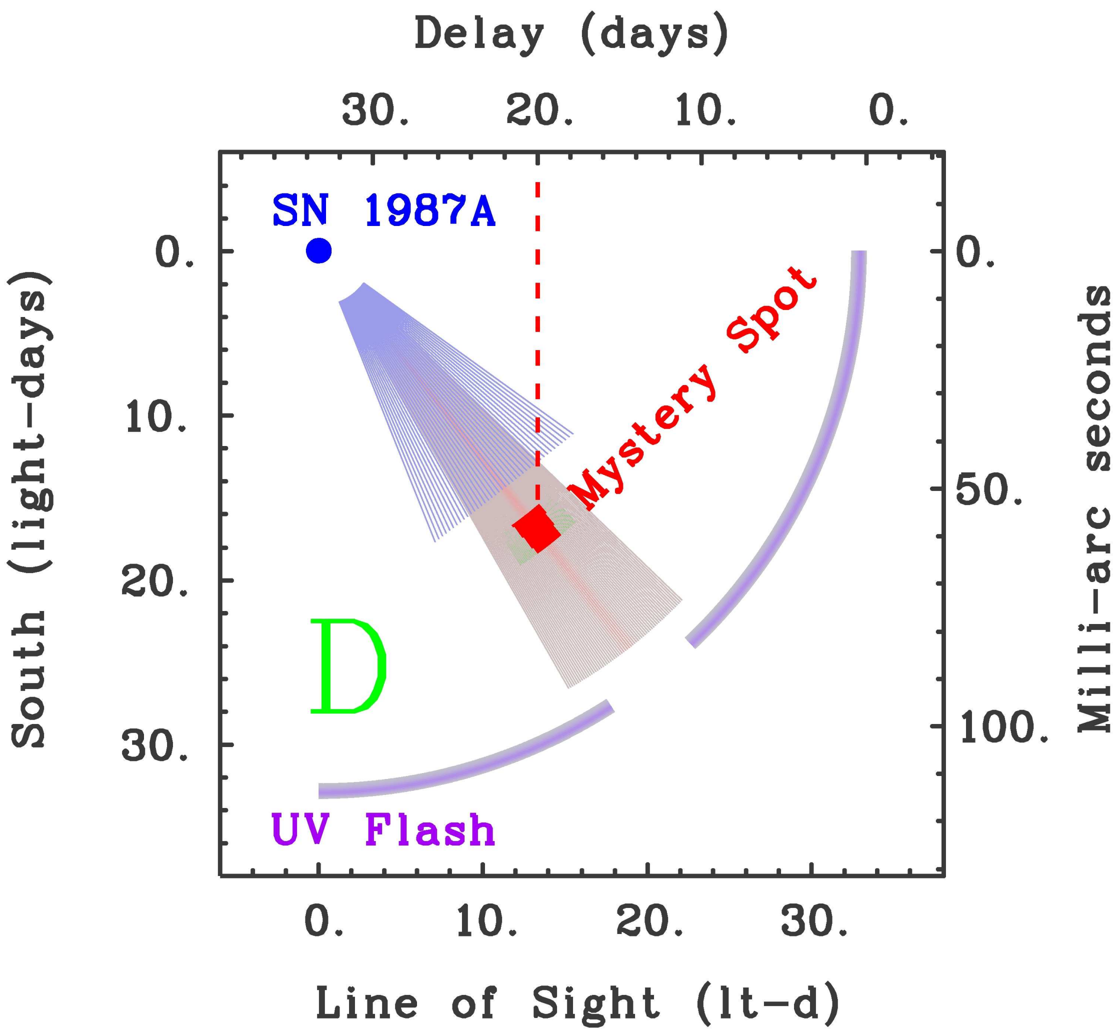

Fig. 15. Particles in the jet continue to impact the polar ejecta (mostly hidden green disk), continuing the ramp in luminosity visible in Fig. 6 near day 20 (top scale for the red strip in *this* figure [15]). By this time the rise from the 87A photosphere proper begins to contribute to the overall luminosity. Thus the MS luminosity can amount to no more than ~5×10^{40} ergs/s, or magnitude 5.8 (see Fig. 6), about 23% of the total optical flux of 2.1×10^{41} ergs/s at day 20. A lifetime of 6×10^{6} s yields the MS total optical output of 3×10^{47} ergs. A luminosity decrement of unknown origin appears in Fig. 6 just after this time.

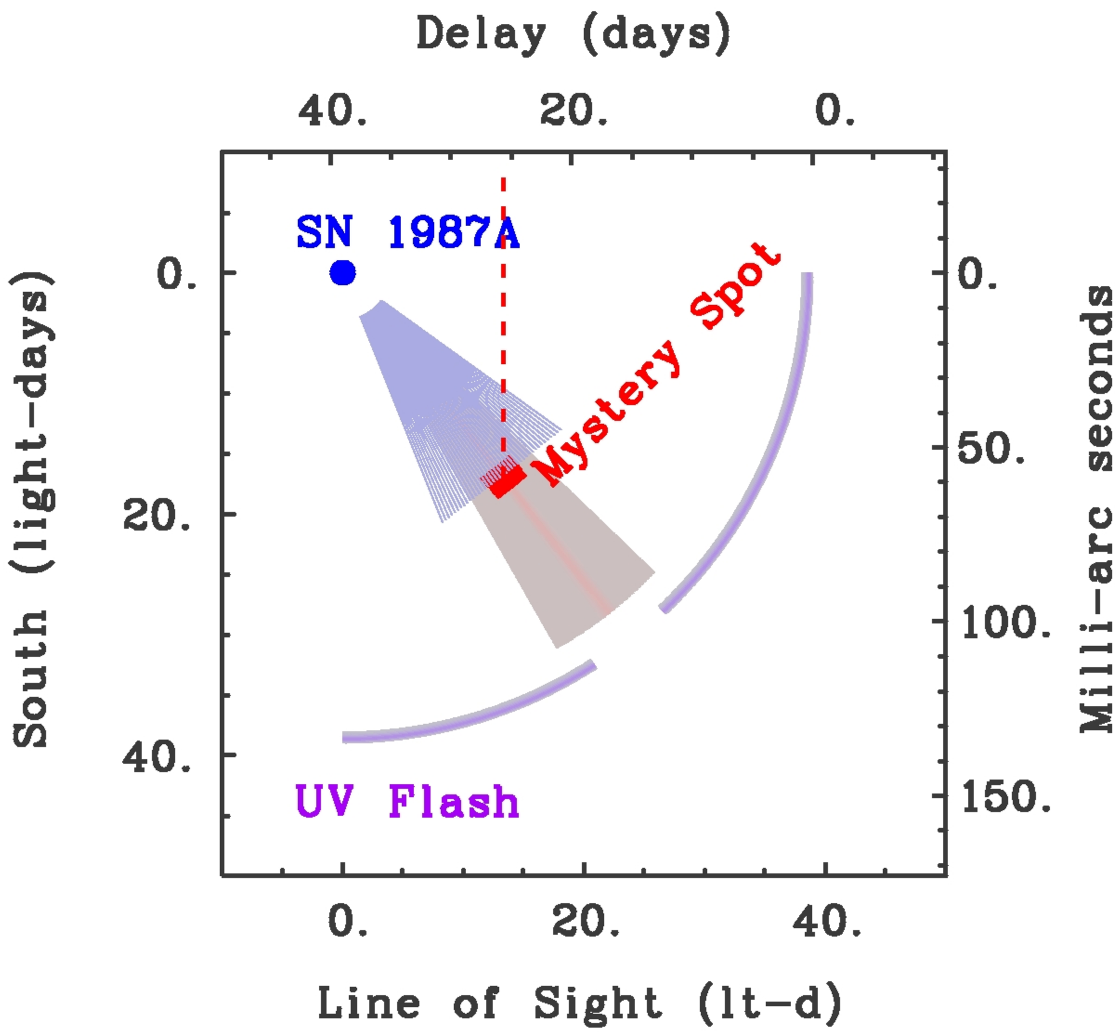

Fig. 16. Particles continue to inject energy into the Mystery Spot around day 26. By this time the MS has become *more spherical*, to account for MS luminosity at days 30, 38, and 50. Penetration of a very deep (~20 light-days) polar ejecta being ruled out by the consistent MS offset measures plotted in Fig. 2. There is no hard limit on its width at this late stage, other than the widths inferred from Fig. 3.

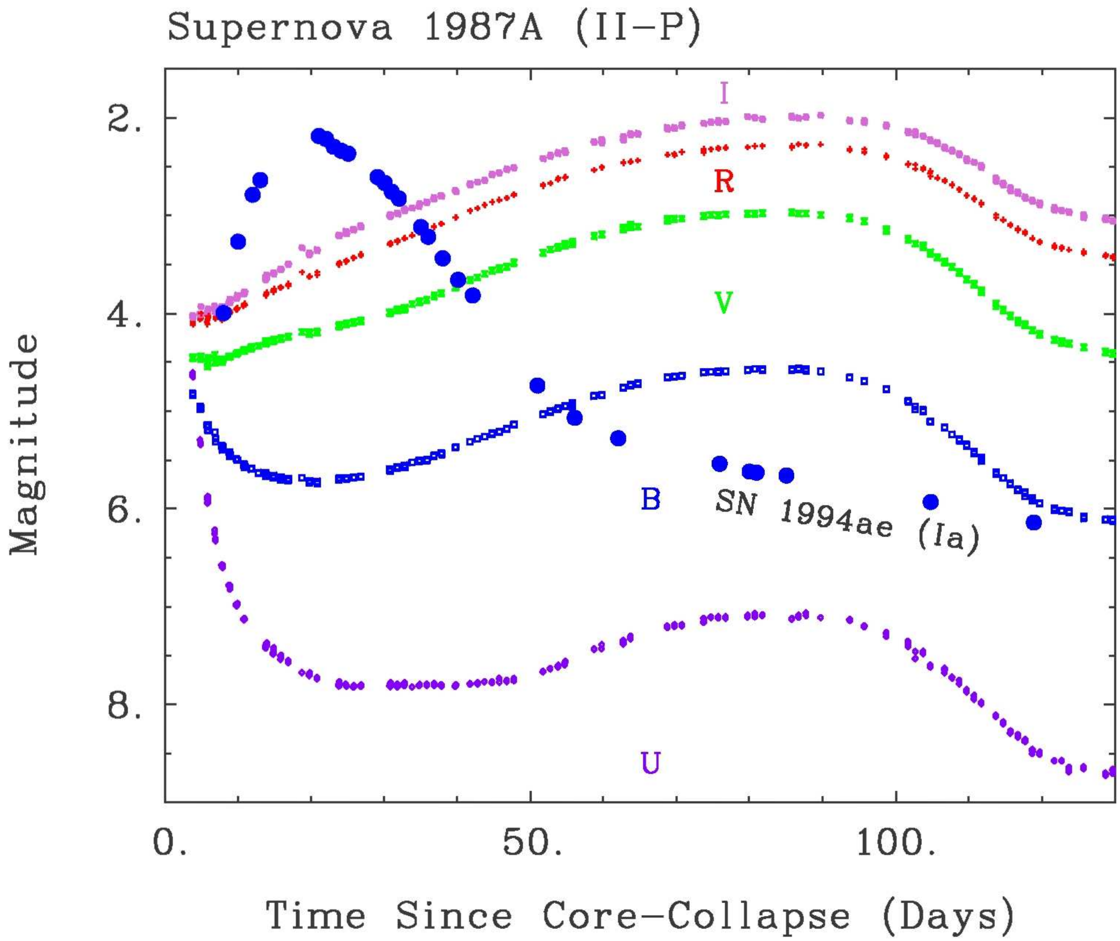

Fig. 17. The early light curve (luminosity history) of SN 1987A from CTIO (Hamuy & Suntzeff 1990, AJ, 99, 1146) in the five bands, U, B, V, R, and I, for the first 130 days following core-collapse, and the B light curve from the Type Ia SN 1994ae (blue disks -- from Riess et al. 1999, AJ, 117, 707), offset by -11 mag. The spike near day 20 in B, R, & I light from SN 1987A corresponds to about 10^{40} ergs/s (see Fig. 6). Is this polar ejecta running out of particles (hence the following decrement)? The agreement of the magnitudes of Fig. 2 and Fig. 6 at day 20 would argue that it is.

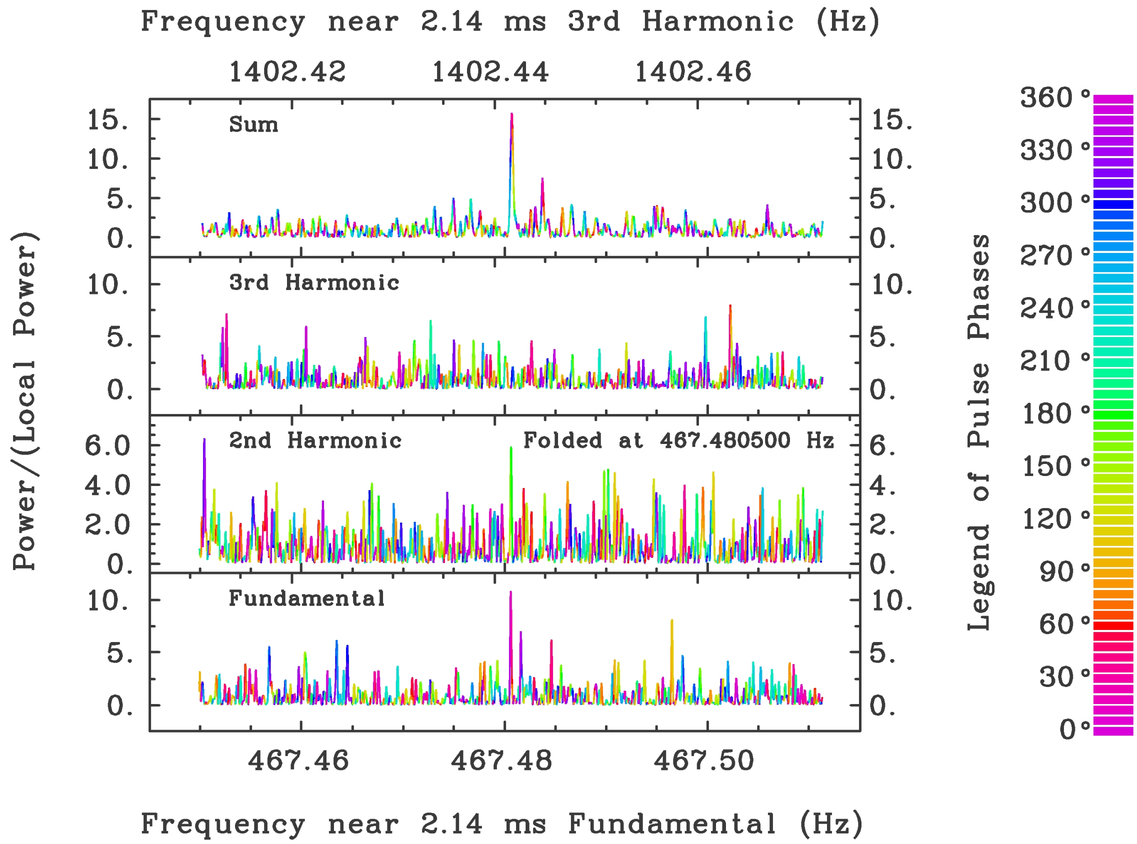

Fig. 18. (Lower three frames) The Fourier power spectra plotted for frequency regions near 467.4805 Hz and its first two higher harmonics from data taken with the Univ. of Tasmania Canopus 1-m Telescope during mid UT July 26, 1993. (Top frame) The sum spectrum of frequencies near the fundamental and 2nd harmonic. The peak in the sum spectrum near 1402.4417/3 = 467.48056 Hz is significant above the five sigma level (probability ~1:6,500,000). The second highest peak corresponds to the 1,000 s modulation seen in many other observations. The first 3 results from Tasmania confirmed the reality of the 2.14 ms optical pulsar in SN 1987A (get used to it, the probabilities in Middleditch et al. 2000, New Astronomy, 5, 243, aren't off 8 orders of magnitude).

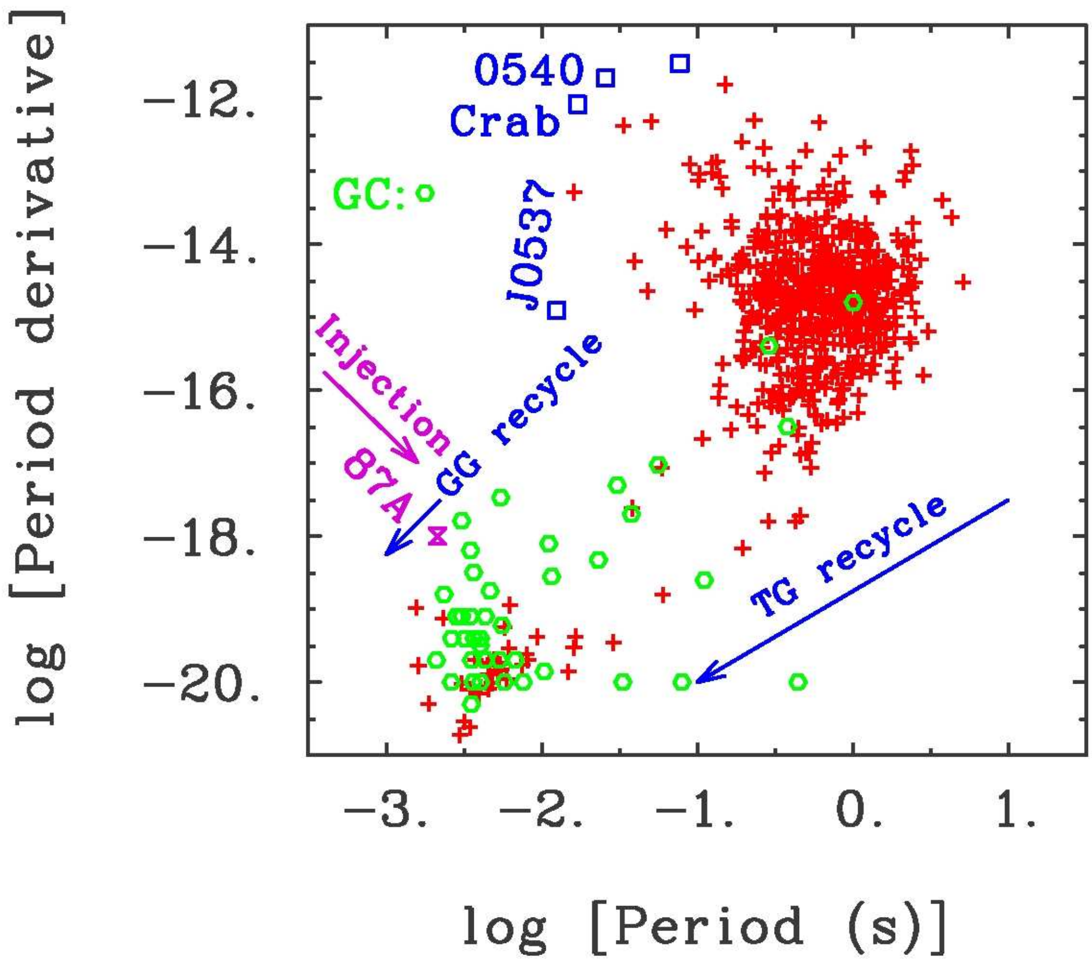

Fig. 19. About 700 pulsars scattered in the P-Pdot plane, some in globular clusters (green circles), most not (red +'s). Injection of a population of 2 ms pulsars occurs near the 87A point (magenta hourglass), most of these radio quiet (as with the Cas A X-ray point source). From there, most move a little right and down quickly due to gravitational radiation, where some are recycled, by accretion from merger-leftover companions, to periods shorter than 2 ms (gigaGauss [GG] recycle), moving to the left (& possibly also downward). Teragauss (TG) pulsars are recycled from the main group down and to the left, but generally not very far (in frequency) because of their high magnetic fields.

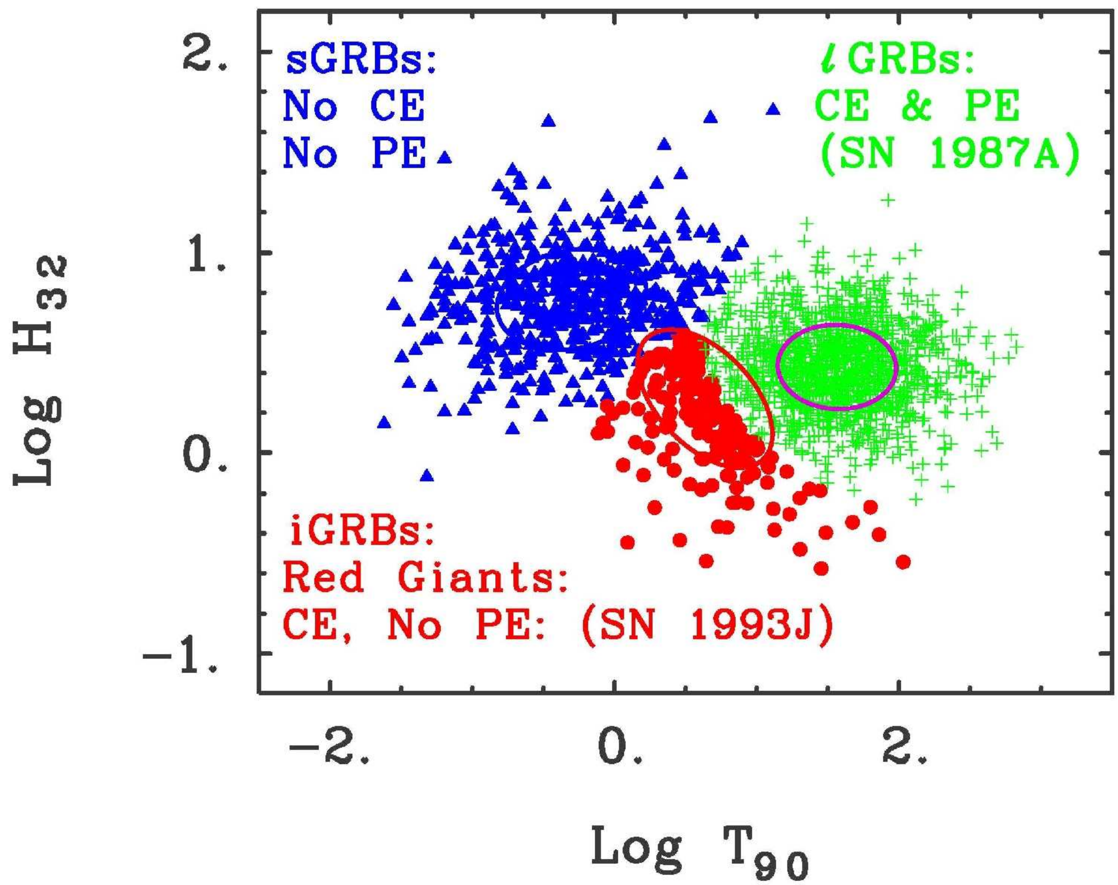

Fig. 20. After Horvath et al. 2006, A&A, 447, 23, the GRBs from the BATSE catalog (Meegan, et al. 2001, http://gammaray/msfc,nasa.gov/batse/grb/catalog/) are scattered in duration (T_{90})-hardness (H_{32}) space. The new third region (red) may be characteristic of merger-induced core-collapse within red *supergiants*, (the early polarization of SN 1993J was *twice* that of SN 1987A). Only short, hard (s)GRBs (blue triangles) are found in elliptical galaxies, yet WD-WD (core-core) merger (DD), as in SN 1987A, makes, or tries to make long, soft (ℓ)GRBs (green '+'s), and must dominate all other mechanisms (as always through binary-binary collisions), such as NS-NS merger, *in* those ellipticals, even when requiring enough mass to produce core-collapse. Thus most of the sGRBs in ellipticals are due to DD, but without

having to pass through common envelope and/or polar ejecta, the means by which they otherwise become ℓGRBs, or intermediately long, softest iGRBs (red disks). Optical afterglows from sGRBs, with no associated SN explosion, indicate core-collapse with total merged mass very near 1.4 $M_\odot$.

The Top Ten Reasons Why Ia SNe Aren't Single Degenerate

1. Hydrogen
2. Helium
3. High Velocity Features
4. Polarization $\propto$ 1/Luminosity
5. SiII " " $\propto$ 1/Luminosity
6. No Ia Radio SN
7. NGC 1316 – 4 Ia's/26 Years
8. >1.2 $M_\odot$ ^{56}Ni (2003fg)
9. CVs are explosive
10. Need Core–Collapse for Zn

Fig. 21. The top ten reasons why Type Ia SNe can't be single degenerate (gradual accretion of a white dwarf past the Chandrasekhar mass limit of 1.4 $M_\odot$).

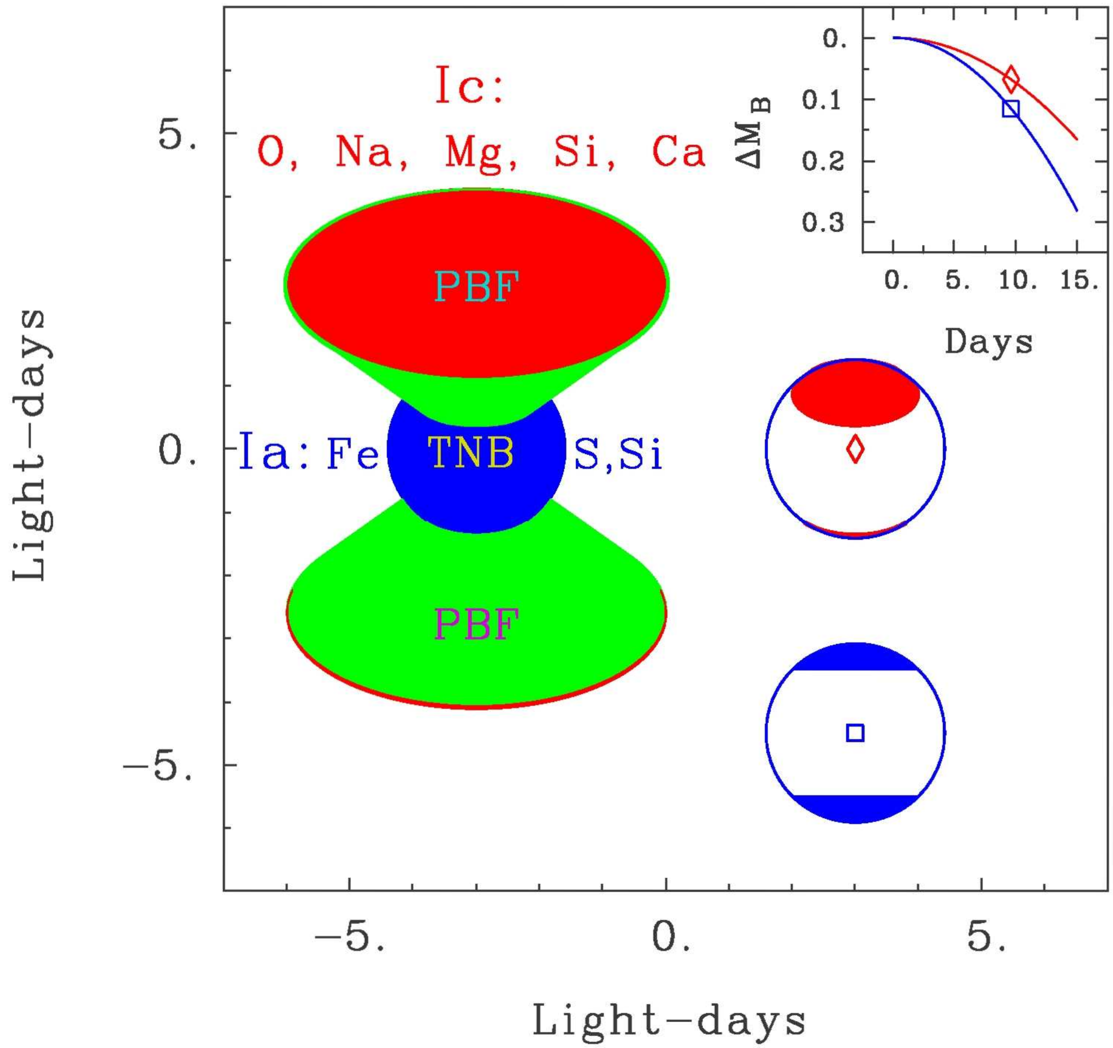

Fig. 22. The geometry for Type Ia SNe, as viewed 30^o off the merger equator. The thermonuclear ball (TNB), whose luminosity is dominated by the decay of ^{56}Ni, is shown in blue, while the polar blowout features (PBFs), each with a half angle of 45^o, are sketched as cones with green surfaces and red ends on the left. Systematics can occur because there is less material to be ejected in Ia PBFs than in those of Type II SNe such as 1987A, and as a consequence the Ia PBFs are ejected with a higher velocity, possibly exposing the PBF footprint on the TNB, shown for co-inclination (co-i) 30^o in red/blue on the right (upper/lower), during the interval when Δm_{15} is measured (inset

in uppermost right -- the curves are for an intrinsic Δm_{15} of 0.5 mag). If TNBs start out as toroids, as seems likely, the difference between the red and blue curves could easily be twice as large, particularly for low co-i's, accounting for the full effect in Ia cosmology. Also, as drawn at upper left, Ia's viewed pole-on are Ic's, given sufficient matter in the overlayer. Otherwise, it would just beg the question of what Ia's viewed from the poles *would* look like.

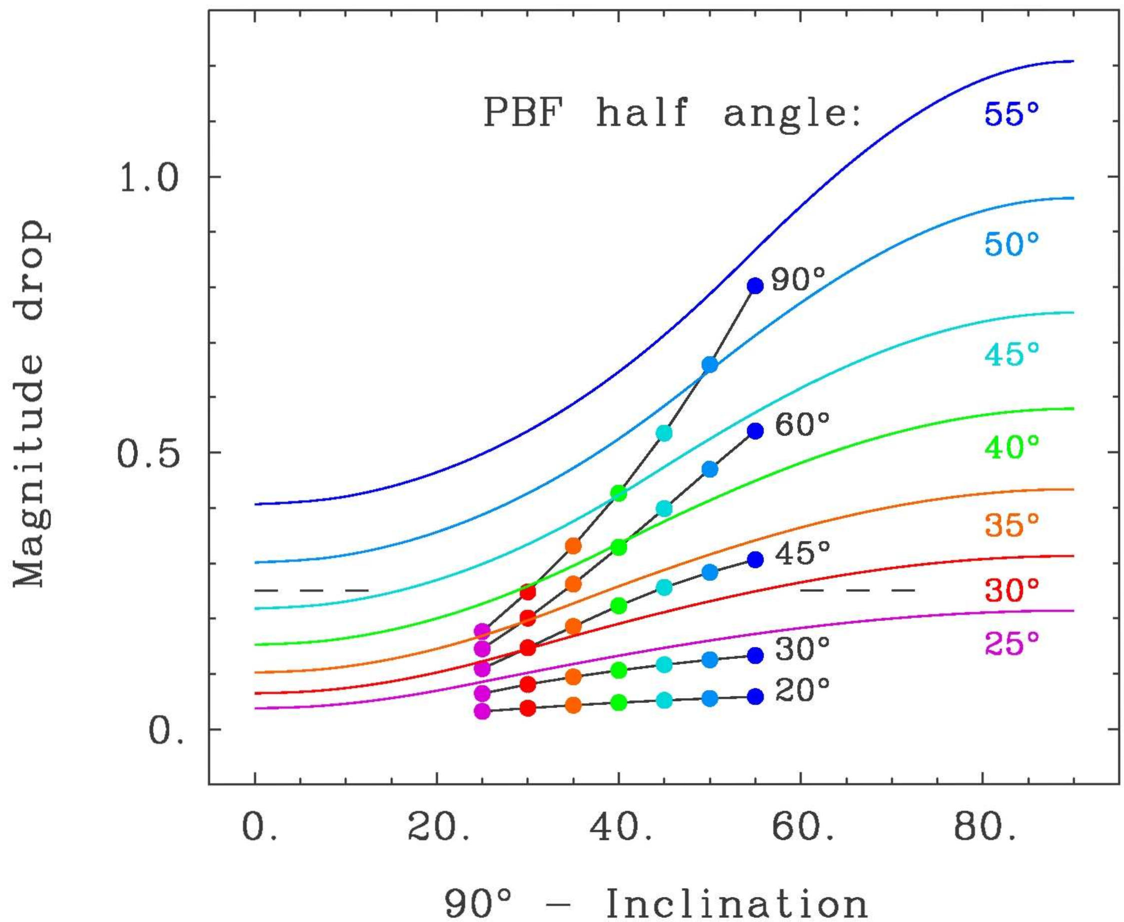

Fig. 23. The maximum drop in magnitude from exposure of the PBF footprint(s) to an observer are plotted as a function of co-inclination for PBF half angles of 25-55°, assuming no contribution to the change in luminosity from the PBFs themselves. The curves with disks represent the *changes* in the

drops in magnitude between the co-i's labeled at their right hand ends, and the drops at 0^o co-i, and the points are plotted on the abscissa at co-i's corresponding to their PBF half angles. The dashed lines represent the effect needed to spuriously produce $\Omega_\Lambda = 0.7$.

Conclusions

SN 1987A was caused by a merger of two stellar cores, and is the Rosetta Stone for 99% of gamma-ray bursts (GRBs), millisecond pulsars (MSPs), & SNe, including all in the modern era except SN 1986J & the more distant 2006gy. The collimation factors for its beam and jet, which produced the "Mystery Spot," both likely exceed 10^4. The pre-CE/PE impact initial photon spectrum of all GRBs, except those from SGRs, is known (and that one's known anyway), and NS-NS star mergers may not make GRBs as we know them, or be as common as previously thought. Short, hard GRBs (sGRBs) from elliptical galaxies are overwhelmingly due to (mostly binary-binary) collision-induced WD-WD merger in their globular clusters (GCs). This is the way 99% of the MSPs in non core-collapsed GCs are formed, all at rotation periods near 2 ms, as happened in SN 1987A, why most sGRBs are offset from the centers of their host elliptical galaxies, and why some show optical afterglows but no SNe. These will have only weak magnetic fields, and some will end up accreting from a binary companion left over from the collision (there are *two* suspects which can do this for binary-binary collisions) to spin periods *shorter* than 2 ms. The moderately fast pulsars in the GCs are due to spinup of neutron stars with TeraGauss magnetic fields (a validation of Ghosh and Lamb, 1979ApJ…234..296G, without needing field decay at *any* time). Like SN 1987A, Type Ia SNe are due to mergers of stellar cores, and when observed from their merger poles will be classified as Ic’s, if sufficient matter exists in the layer above core-collapse to hide the thermonuclear ashes of Fe, S, and Si. There is no need to invent collapsars, hypernovae, supranovae, or super-Chandrasekhar mass white dwarfs. The hitherto unrealized complicated nature of Type Ia SNe may have caused the local sample of Ia's to have been selected as too bright, due to characteristics which are not as obvious in the distant sample, thus producing an apparent anomalous dimming of the cosmological sample. Thus there may be no Dark Energy. There may also be no Dark Matter (Nelson & Petrillo 2007, BAAS, 39, 1, 184). Rejecting the hypothesis of super-Chandrasekhar mass white dwarfs, the >1.2 $M_\odot$ of ^{56}Ni produced in SN 2003fg means that the burn/detonation process in layers of mixed thermonuclear fuel above core-collapse can be very efficient (see immediately below regarding SN 2006gy), spectroscopic "demands," of large amounts of unburned TN fuel, being invalid because of the wrong assumed paradigm (single degenerate) for Ia's. The paltry amounts of ^{56}Ni produced in Type Ib's and >90% of Type IIs is the result of dilution of their TN fuel, such as Si, Ne, O, and C, with He and possibly H due to the merger process prior to core-collapse. SN 2006gy produced 20 $M_\odot$ of ^{56}Ni, not because it was a pair instability SN, but because it was an iron photo-dissociation catastrophe SN of a massive star which underwent core-collapse underneath 25-30 $M_\odot$ of TN fuel, undiluted by He and H (see immediately above regarding 2003fg). Thus a hot center for SN 2006gy will eventually be found, as was found in SN 1986J. Split emission lines can be sporadically observed in Type Ic SNe (and even some classified as Ia's), because of the double degenerate geometry, and these are *not* obviously confirmatory evidence for collapsars.

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